

## **Integration of Correlation Processes in Design Systems**

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### **Abstract**

The integration of correlation processes in design systems has as a target measurements in 3D directly and according to the users criteria in order to generate the required database for the development of the project. In the phase of photogrammetric works, internal and external orientation parameters are calculated and stereo models are created from standard images. The aforementioned are integrated in the system where the measurement of the selected items is done by applying developed correlation algorithms. The processing period has the tools to carry out the calculations in an easy and automatic way, as well as image measurement techniques to acquire the most correct information. The proposed software development is done on Visual Studio platforms for PC, applying the most apt codes and symbols according to the terms of reference required for the design. The results of generating the data base in an interactive way with the geometric study of the structures, facilitates and improves the quality of the works in the projects.

**Keywords:** Digital Photogrammetry, data fusion, feature extraction, correlation algorithms, quality control;

## 1. Introduction

The study of complex structures propounds the need to apply new technologies to generate, under the control and supervision of those responsible for the design, the most adequate metric information. This problem is beginning to improve with the new developments of measurement procedures and their applications to computer design programmes (Chrismann, 2002). The increasing need to reach productivity and quality in the development of the projects is to obtain an effective interaction between measurement procedures and design projects.

The development of integration of image analysis and GIS, are of great importance in the development of new cartographic applications (ISO/TC 211, 2001). In the GIS systems (Wolf, 2000), the integration of new technologies constitutes one of the major targets nowadays. The current research is concentrating on developing strategies that allow the information to be configured for a feasible application in CAD systems.

The creation and the easy access to the information in raster mode and vector mode with a unique coordinate reference system, e.g. Digital National Framework (Allan, 2000), makes it possible to access the adequate information required in the different phases of the projects.

In the sector of Digital Photogrammetry, Image processing techniques (Dequal, 2000), have contributed to major improvements on raster information. The production of true orthophotos is a way of representation which is progressively acquiring more importance in this kind of application (Braun, 2003). The matrix structure of the pixels that build the image constitute the basic ground of raster information for its processing (Luhmann, 2006). In the correlation processes, the point control measured directly by the user is done through the correct position of homologous points in the two photograms of the stereo-model and the evaluating the correlation factor (Krauss, 1997).

The developments with image processing techniques (Gonzalez, 1993), contribute to important improvements in metric and documental information for the development of architecture and engineering projects (Holland, 2001) along with the progress in the software for computer aided design (Burrough, 1999). The methods of processing metric and documental information developed in the C.A.E. systems (Computer Aided Engineering) or C.A.D. (Computer Aided Design) operated with the adequate data base, are a usual procedure for design projects. However, the incorporation of new measurements to the aforementioned systems has no other way of being put into effect but by interpolation methods, which is a determining factor that can show deficiencies for the correct representation in 3D of specific complex elements.

The solution proposes the orientation of the models with photogrammetric techniques and its subsequent integration in the system for the data base calculations along with correlation processes. The design tools that are to be developed should allow an interactive process between measurement techniques and the design works for the user to carry out selective measurement with the adequate accuracy.

## 2. Methodology

The processing system operates with its own image format developed with the following features: partition of the image in tiles with 128\*128 pixel blocks and the production of pyramid images adjusted with a Laplacian filter allowing a fast visualization and processing of the image. This format facilitates a quick and ordered management without loss resolution, assuring good results in correlation processes and minimizing problems in low contrast areas. The file provides a header with information related to orientation parameters, reference systems, image and pixel size, number of pyramid images and the number of rows and columns of the image.

The operating method consists of the integration of the stereo model systems developed through photogrammetric methods, producing epipolar images with internal and external orientation parameters and applying collinearity equations for a constant value of Z. The object points coordinates which are subject to measurements are obtained by applying the unidimensional correlation process in normalized images. Therefore, the amount of calculations in search submatrixes and their errors are reduced.

### 2.1. Correlation algorithms

The identification of homologous points in normalized images is carried out by applying the Area Matching procedure (AM) in the configuration of colour pyramid images (Krauss, 1993). In each of the radiometric components (R,G,B), the correlation coefficient is calculated and the average value is given as a similarity value calculated from the standard deviation ( $\sigma_L$ ,  $\sigma_R$ ) and the covariance ( $\sigma_{LR}$ ) of each of them.

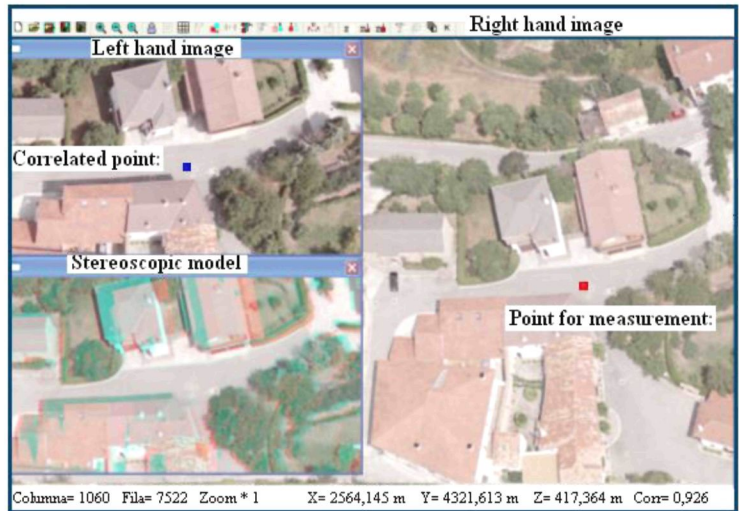
$$\rho = (\rho_R + \rho_G + \rho_B) / 3 \quad (1)$$

The correlation coefficients R are calculated according to the following:

$$R = \frac{\sum_1^n f_1(x_1, y_1)_i \cdot f_2(x_2, y_2)_i}{\sqrt{\sum_1^n f_1^2(x_1, y_1)_i \cdot \sum_1^n f_2^2(x_2, y_2)_i}} \quad (2)$$

where  $f_1$  is the reflectance density of the pixels of the pattern submatrix,  $f_2$  in the search matrix,  $i$  the number of the selected pixels and  $n$  the total of the matrix.

These procedures which are common in photogrammetric correlation are applied in the three options of processing that have been developed: automatic, semiautomatic and manual. In figure II the image portions a) and b) present an adequate texture to apply to automatic and semiautomatic methods, allowing the correct application of the process. Image c) can cause certain difficulties for the identification of pattern and search submatrixes, the solution is in applying stereoscopic methods.



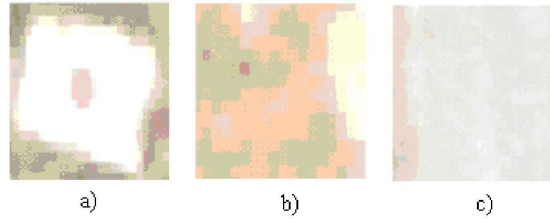


Fig. 1. Photogrammetric correlation process

Fig. 2. Identify the correct position of the homologous point

The correlation algorithms are applied through virtual models without the need of previous experience in stereoscopic vision. In order to obtain the correct adjustment between the pattern submatrixes and search submatrixes, the user selects the point that is to be measured on the right hand or visible image and at the same time it shows a small reference window with the same area of the left hand image of the virtual mode to identify the correct position of the homologous point (Fig. 2).

There are three ways to carry out the correlation: automatic semiautomatic and manual. In the automatic mode, when selecting the point for measurement on the right hand image the process is done in an automatic way and the left hand image reference window opens to the corresponding zone, the target is to identify the correct position of the homologous point and to control its accuracy through the correlation coefficient value. In the semiautomatic option it is necessary to select the near area of the point for measurement and then activate the correlation process.

This mode is important for areas where details are very homogeneous, a common case in those uniformed textured surroundings or points where there is no acceptable geometric definition and so the automatic identification of the selected point between the search and capture zones is difficult.

In urban areas or in low contrast images, the differences between pattern and search matrixes, unables the use of the aforementioned types of correlation. The solution is to apply the manual correlation procedure. The system provides tools that facilitate 3D vision, through devices which allow an automatic correction of the parallaxes (Fig. 3).

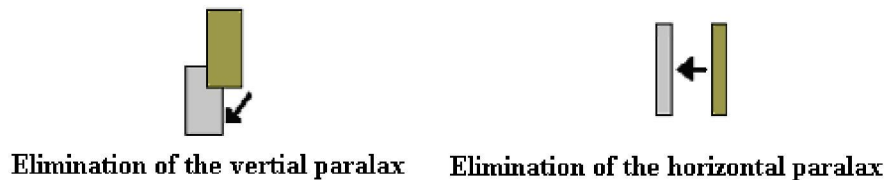


Fig. 3. Manual correlation procedure

The operating of these procedures in design system, is done through a quick and easy process which allows the user to do the calculations and quality control of the coordinates of the selected elements.

## 2.2. Processing and registration of the information

The processing of the information is organized as in any Windows application with the help of three operating bars. The tool bar (Fig. 4) aims at the metric processing in 2D and 3D versions of raster information. It has automatic and semiautomatic correlation processes and the anaglyph configuration is activated in the case of stereoscopic measurements. The images to be studied can be registered in BMP format, for its exportation to other systems.



Fig. 4. The raster toolbar

The vectorial toolbar shows symbols and codes (points, lines and surfaces) for the drawing of the elements that are to be measured and their control and registration. The registration files, can change format for its processing in other systems.

The status toolbar (Fig. 5) shows the result of the operations that have been performed: row and column of the pixel in the image, coordinates X,Y,Z of the selected point with the value of the correlation factor.

Column = 3510 Row = 4208 X = 751.561,600 Y = 4.519.326,720 Zoom x 1 Z = 869,425 Cor = 0,91

Fig. 5. The status toolbar

These tool bars together with navigation help windows (Fig. 6) facilitate the measurements of the project models.

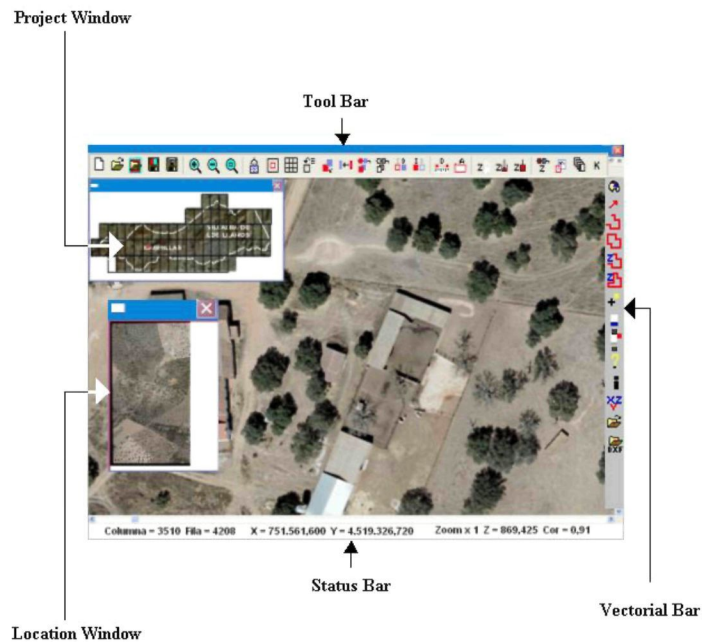


Fig. 6. Display software developed

### 3. Results

The accuracy in the definition of the correlation process in coordinates  $x,y,z$ , is function of the correlation method which is used and with the rigour in the generation of stereo models in digital photogrammetry equipments. The root mean errors in the determination of isolate points\* coordinates from the pair of photographs, are mathematically expressed with the following formulae:

Where  $m_x, m_y$ , are the measurement errors of the coordinates  $x,y$  in the image and  $m_p$  in the determination of the longitudinal parallax  $p$ .



The accuracy in this expression comes from the rigour in the building of photogrammetric models (Chibunichev, 2005). These circumstances imposes the control in the generation of the models by photogrammetry, through camera calibration parameters, internal and external orientation, as well as the coordinates of the control points to obtain the correct accuracy applying the unidimensional correlation process with the following formulae:

$$\left. \begin{aligned} x_0 - f \frac{a_{11}(X - X_s) + a_{21}(Y - Y_s) + a_{31}(Z - Z_s)}{a_{13}(X - X_s) + a_{23}(Y - Y_s) + a_{33}(Z - Z_s)} - x &= 0 \\ y_0 - f \frac{a_{12}(X - X_s) + a_{22}(Y - Y_s) + a_{32}(Z - Z_s)}{a_{13}(X - X_s) + a_{23}(Y - Y_s) + a_{33}(Z - Z_s)} - y &= 0 \end{aligned} \right\} \quad (3)$$

In the correlation measurements, the accuracy is similar to the one obtained in the isolate points through photogrammetric methods. The tests performed in the correlation processes, in reference to the application of the algorithm for each of the radiometric elements and the definition of the most suitable size of the submatrixes, in automatic and semiautomatic categories, have proved the advantages of the semiautomatic mode, for both its accuracy and facility in measurement control.

\*Isolate point: A stereoscopically measured point on a surface in a free obstacle and vegetation terrain which expresses the accuracy in the photogrammetric model in an objective way.

The tests which have taken place in order to evaluate the accuracy in the different correlation algorithms, were compared to premarked control points and with measurements in different texture terrain (Fig. 7), applying the isolate point principle with photogrammetry technics. These results were determined with aerial digital photographs models at scale 1/7000 and 15 cm pixel size.



Fig. 7. Control points and with measurements in different texture terrain

The check or control points measured on the terrain I-1, I-2 and I-3 were marked with a 60 cm square side, the same size as the pattern submatrix of 5 x 5 pixels. The differences between the control points and the ones measured by correlation (Table 1), correspond to the standard accuracy of isolate points obtained through photogrammetric technics ( $\sigma_x = \sigma_y = 15$  cm;  $\sigma_z = 20$  cm), the high correlation average value ( $\rho = 0,980$ ) justifies the quality of the process.

Table 1

<i>Premarked points</i>	<i>Differences between correlated and control points: cm</i>			<i>Corr. Coef.</i>
	$\Delta X$	$\Delta Y$	$\Delta Z$	
I-1	12,21	13,12	18,46	$\rho = 0,982$
I-2	15,20	14,80	20,10	$\rho = 0,979$
I-3	10,25	14,70	18,55	$\rho = 0,984$

In terrains with suitable textures and without trees, in the fragments of the images which are subject to correlation (II), the differences in the coordinates x,y between the automatic or semiautomatic correlation calculated points and the average points measured by conventional photogrammetry, according to the concept of isolate points, show an average value corresponding to the size of 1 pixel (15 cm) and near 0 for the coordinate z. The correlation coefficient value is higher than 0,9; (Table 2).

Table 2

<i>Zone II</i>	<i>Differences between correlated and photogrammetric points: cm</i>			<i>Corr. Coef.</i>
	$\Delta X$	$\Delta Y$	$\Delta Z$	
1	0	15,30	0	$\rho = 0,908$
2	30,50	15,20	5,00	$\rho = 0,962$
50	10,00	15,30	0	$\rho = 0,946$

In zones (IV) without an appropriate contrast in the images, the correlation coefficient is  $\rho \leq 0,6$  and in the buildings (V) it decreases to  $\rho \leq 0,5$ . These circumstances demonstrate the need to apply the manual procedure to obtain the correct measurements. The measurements performed on the 50 selected points, impose as a rule, to reach a similar accuracy between the correlation processes and the isolate point methods for photogrammetric techniques obtaining as a correlation result:  $\rho \geq 0,7$ .

#### 4. Discussion

The different correlation algorithms that have been developed allow the application of the most adequate procedure, according to the geometric and photogrammetric features of the images. The automatic and semiautomatic methods are the fastest and easiest for the user to apply, and in the case that stereoscopic procedures were required, there are devices which easily generate the 3D models to facilitate measurements.

#### 5. Conclusion

The correlation processes integrated in the design systems have as an objective the facilitation of metric and documental measurements to be done directly by the user. The regulations generally demanded in the Technical Specification Sheet are not modified in measurement works. The user decides the accuracy which is required in the data base, the scales of the ortophotos, image ranges and the generation of stereo models for its processing in virtual mode. Photogrammetric works and normalized images are generated for its processing in the system under this criterion. The representation in vectorial mode (plans, sections, etc), in the implementation phase of the project,

applying normalized procedures (ISO; UNE) to obtain the adequate interpretation in the environment of the project is designed by the user.

The designed system facilitates the development of the project from its definition and calculations to the execution processes, under the supervision of the ones responsible for the design. It has the necessary tools to effectively interact with the generated data base, the raster and vectorial information and the design of the project.

The measurements by correlation reach similar accuracy to the one obtained by photogrammetric methods according to the concept of isolate points. The structure of the system allows the appliance of normalized procedures, facilitating the supervision works and increasing the productivity and quality of the projects.

The information configured in this way has proven its feasibility to exportation to other programs, e.g. C.A.D. This interest is justified by the added features which can contribute to its study and analysis due to the training of the technicians who participate in these works.

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